

GEOLOGY OF THE AREA OF BAHÍA BLANCA, DARWIN'S VIEW AND THE PRESENT KNOWLEDGE: A STORY OF 10 MILLION YEARS

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ABSTRACT

The aim of this paper is to give an updated outlook of the scenery described by Charles Darwin when he visited Bahía Blanca and surrounding areas, following the itinerary during his voyage on board HMS Beagle. Such an outlook is a state of the art of the current understanding of the Late Miocene-Holocene history in the southwestern Pampas (Argentina). Multidisciplinary results were integrated in a chronosequence chart synthesizing the suggested space-time correlation of the recognized events. Some of the studied localities covering the whole time interval represented in the area were arranged in this chart in a hypothetical E-W line crossing the Río Sauce Grande basin and the surrounding highlands. This line is also approximately the one followed in part by Darwin when riding from Bahía Blanca to Tapalqué (*Tapalguén*) as he crossed the region toward the *Río Sauce*. Paleoenvironmental and paleoclimatic inferences for the last 10m.y. are also given. Paleontological studies included vertebrates, ostracods and palynomorphs. Many of the results of these investigations are the answers to Darwin's question when he first visited the area.

Keywords: *Pampas, Tapalqué, Pampean Formation, Punta Alta, Red earth cliffs.*

RESUMEN: *Geología del área de Bahía Blanca, los comentarios de Darwin y el conocimiento actual: una historia de 10 millones de años.*

El objetivo de este trabajo es brindar una actualización del escenario descrito por Charles Darwin cuando visitó Bahía Blanca y sus alrededores, siguiendo el itinerario de su viaje alrededor del mundo a bordo del Beagle. Se trata de una puesta al día del conocimiento de la historia del sudoeste de la región pampeana (Argentina) desde el Mioceno tardío hasta el Holoceno y tiempos históricos. Las investigaciones multidisciplinarias llevadas a cabo por el grupo de investigación del Laboratorio de Palinología, UNS, Bahía Blanca, se integraron en una carta cronoestratigráfica secuencial, en la cual se sintetizaron las correlaciones espacio-temporales de los eventos reconocidos. En esta carta, algunas de las localidades estudiadas que cubren todo el lapso representado en el área, se ordenaron en una línea hipotética E-O que corta la cuenca del río Sauce Grande y sus divisorias. En parte, esta línea también sigue aproximadamente el primer tramo de la cabalgata de Darwin desde Bahía Blanca hacia Tapalqué (*Tapalguén*), cuando cruzó la región hacia el *Río Sauce*. Asimismo, se brinda información paleoambiental y paleoclimática de los últimos 10 ma para esta región. Los estudios paleontológicos incluyeron vertebrados, ostrácodos y palinómorfos. Muchos de los resultados de estas investigaciones son respuestas a comentarios que Darwin hizo en su visita.

Palabras clave: *Pampas, Tapalqué, Formación Pampeano, Punta Alta, Acantilados de tierras rojas.*

INTRODUCTION

The aim of this paper is to give an updated outlook of the scenery described by Charles Darwin when he visited Bahía Blanca and surrounding areas, following the itinerary during his voyage on board the Beagle (Fig. 1).

Most of the information is taken from Quattrocchio *et al.* (2008) - and references therein - who gave a state of the art account of the understanding of the late

Miocene-Holocene history in the southwest Pampas (Argentina) (Fig. 2). This information was assembled by researchers at the Palynology Laboratory of the UNS (Bahía Blanca) over almost 20 years of mapping, stratigraphic studies and analyses of the fossil record. Paleontological studies included vertebrates, ostracods and palynomorphs. Many of the results of these investigations are the answers to Darwin's comments when he first visited the area. Darwin spent 67

days in this area, from September 7 to October 20, 1832, and from August 17 to September 8, 1833. The amount of geological and biological information provided in his notes and further publications, and the acute observations concerning the genesis of the deposits, the past environments and organisms are overwhelming even today, more than one and a half century later. Only those issues that have been revisited by the authors are here discussed.

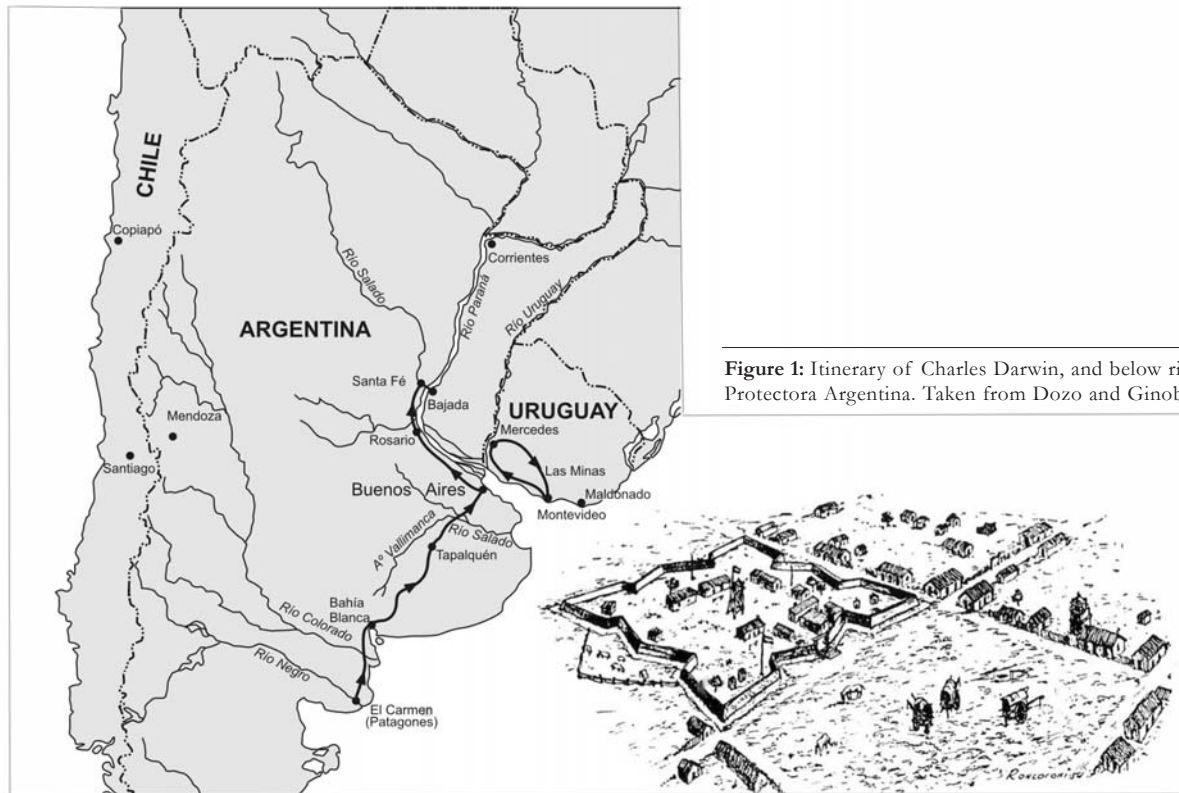


Figure 1: Itinerary of Charles Darwin, and below right, the Fortaleza Protectora Argentina. Taken from Dozo and Ginobili 1999.

Charles Darwin mentioned Bahía Blanca, and described this area several times in his reports. The writer Eduardo Mallea (Bahía Blanca, 1903-Buenos Aires, 1982) already underlined this visit when he wrote in his novel "Todo verdor perecerá" (Mallea 1941): "*Cuántas civilizaciones humanas habían evolucionado y perecido cuando este pedazo de desierto emergía de su sopor! En torno al fortín, valla opuesta al indio predatorio, comenzó a crecer, hacia los ochocientos veintiocho, la población militar, y cuatro años más tarde Rosas y Darwin se paraban ante aquellos salitrales que después de los secos calores extendían en la bahía su ardiente sábana blanca.*" ["All greenness will perish": "*How many civilizations had evolved and perished by the time this piece of desert was emerging from its drowsiness! Surrounding the fortress, boundary for the predatory aborigines, there started to grow, near 1828, the military population, and four years later, Rosas and Darwin stood before those saltpeter beds that, after dry heat waves, spread their fiery white sheet along the bay*"].

THE ARRIVAL

Darwin first saw Bahía Blanca when the

Beagle anchored there on September 6, 1832. "*Baía (sic) Blanca has only been settled within the last six years: previous to which even the existence of the bay was not known. It is designed as a frontier fort against the Indians & thus to connect Buenos Ayres to Rio Negro*" (Keynes 2001). He stayed in the area until October 19, visiting Punta Alta and Monte Hermoso. Then the Beagle went back to Montevideo. On November 28 they sailed again south to Patagonia, and when returning to Buenos Aires, he left the Beagle at Patagonia and rode to Buenos Aires. On August 17, 1833 he wrote: "*Bahia Blanca scarcely deserves the name of a village. A few houses and the barracks for the troops are enclosed by a deep ditch and fortified wall*" (Darwin 1845, p. 76).

Bahía Blanca is located in the southeastern part of the province of Buenos Aires, Argentina, on the Atlantic Ocean. It has a population of 325,000 inhabitants according to the 2005 census. The city was founded as a fort on 11th. April 1828 by Colonel Ramón Estomba (Fig. 3) under the orders of Brigadier-General and subsequent Governor of Buenos Aires, Juan Manuel de Rosas. The original

founding was named Fortaleza Protectora Argentina (Argentine Protective Fortress, Fig. 1), intended to protect settlers and their cattle from raids of native aborigines, and also to protect the coast from the Brazilian navy, which had landed in the area the previous year. The fort was attacked by *malones* (incursions of nomad aborigines on horseback) several times, most notably in 1859 by 3,000 Calfucurá warriors.

About the area, he wrote: "*I have several times alluded to the surface of the ground being incrustated with salt. This phenomenon is quite different from that of the salinas, and more extraordinary. In many parts of South America, wherever the climate is moderately dry, these incrustations occur; but I have nowhere seen them so abundant as near Bahía Blanca. The salt here, and in other parts of Patagonia, consists chiefly of sulphate of soda with some common salt. As long as the ground remains moist in the salitrales (as the Spaniards improperly call them, mistaking this substance for saltpeter), nothing is to be seen but an extensive plain composed of a black, muddy soil, supporting scattered tufts of succulent plants. On returning through one of these tracts, after a week's hot*

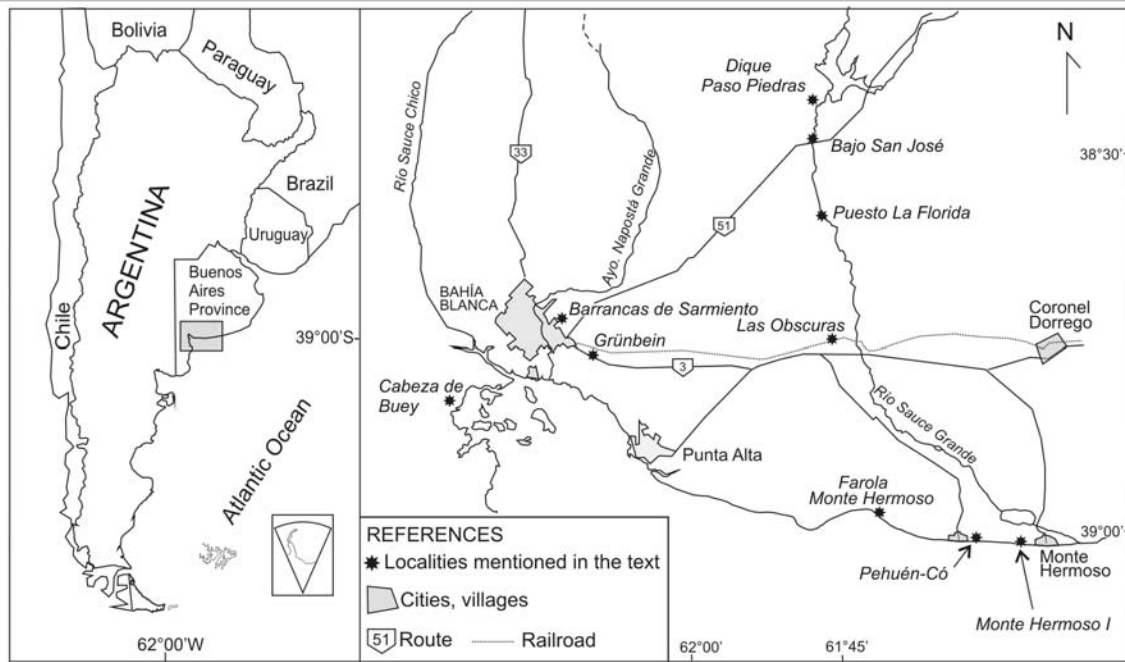


Figure 2: Map of the studied area with the localities mentioned in the text.

weather, one is surprised to see square miles of the plain white, as if from a slight fall of snow..." (Darwin 1845, p. 78).

Bahía Blanca means White Bay. The name is due to the typical colour of the salt covering the soils surrounding its shores. "The wide expanse of water is choked up by numerous great mud-banks, which the inhabitants call Cangrejales, or crabberies, from the number of small crabs..." (Darwin 1845, p. 80).

The bay (which is presently considered an estuary, Perillo *et al.* 2004) was seen by Ferdinand Magellan in 1520 during the first circumnavigation around the world on the orders of Charles I of Spain, as he searched for a pass connecting the Atlantic and Pacific oceans.

Darwin's observations of the area are arranged according to the age of the sediments he described, from the oldest to the youngest.

THE GREAT PAMPEAN FORMATION

"The Beagle arrived here on the 24th of August, and a week afterwards sailed for the Plata. With Captain Fitz Roy's consent I was left behind, to travel by land to Buenos Ayres. I will here add some observations, which were made during this visit and on a previous occasion, when the Beagle was employed in surveying the

harbour. The plain, at the distance of a few miles from the coast, belongs to the great Pampean formation, which consists in part of a reddish clay, and in part of a highly calcareous marly rock" (Darwin 1845, p. 81).

This sedimentation, including both loess (sediments with a high content of volcanic derived particles) and loessoid sediments (reworked loess) (Zárate 2003), was related to a phase of late Miocene (ca. 10 Ma) orogeny in the Andes, which acted as a barrier to moisture-laden Pacific winds. This initiated "the desertification of Patagonia caused by the rain shadow while precocious Pampa environment probably came into prominence at about this time" (Patterson and Pascual 1972).

Traverse (1982) refers to this 10-million-year period as the "Ultimogene". Its inception is based on the presence of practically 100% extant plant genera. By this time, also began the establishment of steppe vegetation, dominated by grasses and by shrubby composites and chenopods in America and Eurasia.

In the southern Pampas (Argentina), at least the last 9-3 Ma record is described as sequences composed of alternating loess and palaeosol units known in general as Pampean sediments (Fidalgo *et al.* 1975) and locally as the Saldungaray, La Toma (Furque 1967), and Monte Hermo-

so (Zavala 1993) formations. These sequences, stretch across South America from 23°S to 41°S (Teruggi 1957, Bargo and Deschamps 1996). They indicate climatic fluctuations, alternating between arid and cold (loess deposition) and warm and humid (palaeosol development) intervals. Further interpretation of these sediments and the related tosa beds are subject of another article in this volume (Zárate and Folguera 2009).

The stratigraphic correlation among exposures of the Pampean sediments is quite difficult because of the lithologic uniformity, but they bear faunas of different ages (from the late Miocene to the Middle Pleistocene) which greatly help in this correlation. The oldest exposures of these Cenozoic sequences in the area are those of Grünbein and Barrancas de Sarmiento near Bahía Blanca city (Fig. 2), including loessoid sediments devoid of pollen, but yielding vertebrate remains. The fauna-especially the octodontoid rodents of the genera *Xenodontomys* and *Phthoromys*-suggests a late Miocene age (Verzi and Deschamps 1996, Deschamps *et al.* 1998, Verzi *et al.* 2008). Other loessoid sediments exposed at Las Obscuras (Fig. 2), in the middle basin of Río Sauce Grande, were also sterile in pollen, but the mammal remains - especially the oc-

ronments might have been similar to the modern Chaqueña Phytogeographic Province with open xerophytic woodlands, but more humid, with seasonal differences in rainfall (Pascual and Ortiz Jaureguizar 1990).

THE LATE PLIOCENE-EARLY PLEISTOCENE

"Even the view was insignificant;-a plain like the sea, but without its beautiful colour and defined outline."

Sea level changes produced different geomorphic features in these homogeneous sediments, including erosion, differences in the equilibrium river profiles, regressive and transgressive events, and building of shell terraces during the regressive phases.

During the late Pliocene-Early Pleistocene interval this area was probably affected by erosion processes (and no deposition; see Fig. 9). In the study area, a single late Pliocene event has been identified in the conglomerates of the La Delta Sequence within the valley of Río Sauce Grande at Dique Paso Piedras (Deschamps 2005). The complex terraces in the Río Sauce Grande (see below) were interpreted within an evolutionary model of valleys in arid-semiarid regions (Zavala and Quattrocchio 2001). In this model, valleys were active only sporadically and most of the time behaved as geomorphologically depressed zones, hosting locally sourced gravitational and aeolian deposits. Geologic and sedimentological data suggest that La Delta Sequence could represent the second stage of initial filling within a transport zone, or zone 2 of the evolution of fluvial valleys in arid and semiarid zones. This process is related to the beginning of a transgressive cycle of an interglacial period. Semidesertic environments that began their development during the global climatic deterioration of the late Miocene were dominant during the Pliocene in western Argentina. The final rise of the Sierras Pampeanas acted as a wind shadow, increasing the desertification of



Figure 4: The red earth cliffs near Punta Alta: Farola Monte Hermoso.

No. 15.—SECTION OF BEDS WITH RECENT SHELLS AND EXTINCT MAMMIFERS, AT PUNTA ALTA IN BAHIA BLANCA.

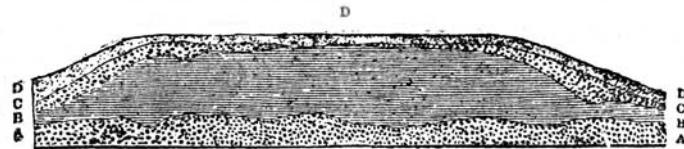


Figure 5: The original drawing of Punta Alta section.

the western areas (Pascual 1984). The caviomorph rodent fauna in the southeastern coast of the Buenos Aires Province, suggests a strong arid pulse at the end of the late Pliocene that could be coeval with the global climatic deterioration at the Gauss-Matuyama boundary (Verzi 2001, Verzi and Quintana 2005).

THE LATE PLEISTOCENE: PUNTA ALTA AND THE MONSTERS OF EXTINCT RACES

The Pleistocene-Holocene is recorded in the coastal area as well as in the valleys of the main rivers of the area. One of the most renowned Pleistocene sites visited by Darwin is Punta Alta. He spent here several days looking for fossils in September and October, 1832 and August 1833: *"We passed the night in Punta Alta, and I employed myself in searching for fossil bones; this point being a perfect catacomb for monsters*

of extinct races." (Darwin 1845, p. 80). Vertebrate fossils are referred to in another chapter of this volume (Fernicola *et al.*). This area is today buried beneath the naval base of Puerto Belgrano and could not be revisited; he reported the description and a drawing of the profile (Darwin 1846, p. 82-83): *"Punta Alta is situated about thirty miles higher up on the northern side of this same bay: it consists of a small plain, between twenty and thirty feet in height, cut off on the shore by a line of low cliffs about a mile in length, represented in the diagram with its vertical scale necessarily exaggerated (Fig. 5). He described four beds (A-D). "The lower bed (A) ... stratified gravel or conglomerate ... curvilinear, owing to the action of currents, and dip in different directions; they include an extraordinary number of bones of gigantic mammifers and many shells... The second bed (B) is about fifteen feet in thickness ... of red, tough clayey mud, with minute linear cavities... The bed (C) is of stratified gravel, like the lowest one... These three lower beds are covered by an unconforma-*

ble mantle (D) of stratified sandy earth, including many pebbles of quartz, pumice and phonolite, land and sea-shells."

The mammal bones found in this section "... were associated with twenty-three species of shells, of which thirteen are recent and four others very closely related to recent forms; whether the remaining ones are extinct or simply unknown, must be doubtful, as few collections of shells have been made on this coast. As, however, the recent species were embedded in nearly the same proportional numbers with those now living in the bay, I think there can be little doubt, that this accumulation belongs to a very late tertiary period" (Darwin 1845, p. 83). The 23 mentioned species are in fact 20 mollusk species, the other three are barnacles (*Balanus*), anthozoan corals (*As-traea*) and bryozoans (*Flustra*), all of them pertaining to the middle Holocene transgression recorded in the Bahía Blanca estuary (Farinati personal communication). Darwin made extensive observations on one pennatulaceous (Coelenterata, Anthozoa) which he named *Vir-gularia patagonica*, but known today as *Stylatula darwini* (Farinati 1989): *At low water hundreds of these zoophytes might be seen, projecting like stubble, with the truncate end upwards, a few inches above the surface of the muddy sand*" (Darwin 1845, p. 99).

Especially noteworthy in this area, although not seen by Darwin, is the record of fossil trackways discovered by researchers of the UNS some kilometres east of Punta Alta (Fig. 2), in the paleoichnological site of Pehuén-Có (Fig. 6a). These trackways are quite rare in the fossil record, particularly in such amounts, and have been visited by researches of many foreign countries. They belong to birds, xenarthrans, camelids, macraucheniiids, and were dated in $12,000 \pm 100$ years ^{14}C BP. They have been extensively studied by Drs. Manera and Aramayo (Aramayo and Manera de Bianco 1996, Quattrocchio and Borrromei 1998). (Fig. 6a) Another outstanding record in this area is that of early aborigines' footprints (Fig. 6b) which were found at the Monte Hermoso1 site and were dated in 7,000 years BP (Bayón and Politis 1996, Zavala *et*

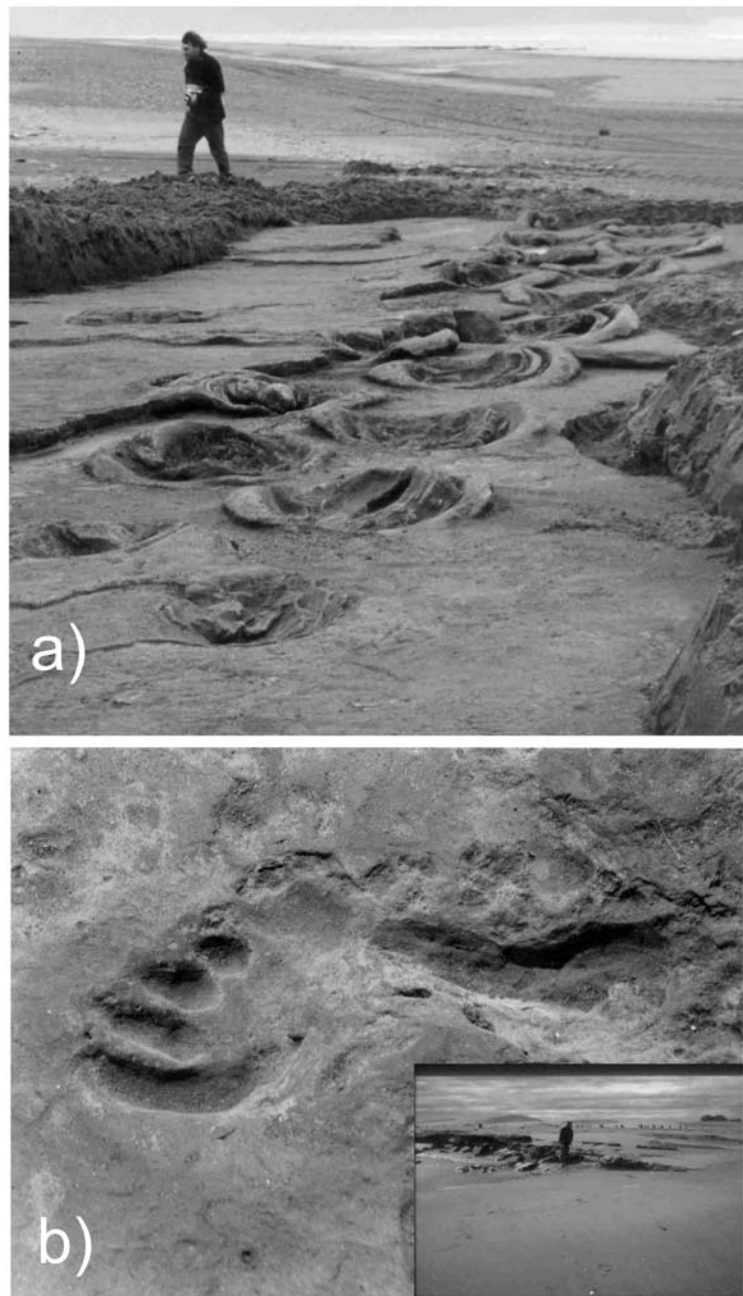


Figure 6: a) Trackway of *Megatherium* on Pleistocene sediments of the Pehuén-Có ichnological site. b) Human footprint on Holocene sediments of the Monte Hermoso I archaeological site.

al. 1992).

THE RIO SAUCE

The Late Pleistocene-Holocene is also recorded in the valleys of the main rivers which flow across Tertiary units. The Río Sauce Grande is the main river in the southwestern Pampas, and Darwin cross-

sed it ridding to Buenos Aires on September 8th. 1833: "I hired a Gaucho to accompany me on my ride to Buenos Ayres... The distance to Buenos Ayres is about four hundred miles, and nearly the whole way through an uninhabited country. We started early in the morning; ascending a few hundred feet from the basin of green turf on which Bahía Blanca stands, we entered on a wide desolate plain... Af-

ter a long gallop, having changed horses twice, we reached the Río Sauce: it is a deep, rapid, little stream, not above twenty-five feet wide. The second posta on the road to Buenos Ayres stands on its banks; ..." (Darwin 1845, p. 106; Figs. 7 and 8).

Remains of three levels of ancient terraces assigned to La Delta (see above), San José and Agua Blanca sequences (dated as late Pliocene, Middle Pleistocene and Late Pleistocene-Holocene respectively; Zavala and Quattrocchio 2001, Deschamps 2005), document different episodes of incision and valley infilling.

The middle Pleistocene was particularly studied at Bajo San José, represented by the Bajo San José Sequence, which was deposited by a braided river, typical of arid to semiarid environments. The characteristic longitudinal bars and channels infilling would have provided varied niches for the rich fauna found in these deposits (Deschamps and Borromei 1992, Deschamps 2003, 2005). No pollen was found, but mammals, especially the octodontoid rodent *Ctenomys kraglievichi* as well as murid rodents and Tayassuidae, suggest the strongest warm pulse so far recognized in the Middle Pleistocene (Bonaerian age) of southern South America (Verzi *et al.* 2004).

THE VEGETATION AT THAT PERIOD

Darwin wondered about the vegetation coexisting with the large Late Pleistocene mammals of Punta Alta: "What, it may naturally be asked, was the character of the vegetation at that period; was the country as wretchedly sterile as it now is? As so many of the co-embedded shells are the same with those now living in the bay, I was at first inclined to think that the former vegetation was probably similar to the existing one; but this would have been an erroneous inference, for some of these same shells live on the luxuriant coast of Brazil... Nevertheless, from the following considerations, I do not believe that the simple fact of many gigantic quadrupeds having lived on the plains round Bahía Blanca, is any sure guide that they formerly were clothed with a luxuriant vegetation: I



Figure 7: The Río Sauce Grande and Sierra de la Ventana, with aborigines as drawn by E. Lassalle in 1827 during the voyage with the French naturalist Alcide d'Orbigny.



Figure 8: The Río Sauce Grande today.

have no doubt that the sterile country a little southward, near the Río Negro, with its scattered thorny trees, would support many and large quadrupeds" (Darwin 1845, p. 84-85). This latter issue is developed in another article of this volume (Vizcaíno *et al.* 2009), but pollen and ostracod analyses performed at several localities of the Río Sauce Grande (e.g. Puesto La Florida, Fig. 2), and Arroyo Napostá Grande, including one site at the outlet near Punta Alta (Bertels and Martínez 1990, Borromei 1992, 1995, 1998, Grill 1993, 1995, 1997, Martínez 2002) provided information about the vegetation and climate. These analyses suggest arid conditions associated with more continental environments

and related to lower sea level in the Atlantic coast of Buenos Aires province (Quattrocchio *et al.* 1995, 1998), quite different from "the luxuriant vegetation" and close to a "sterile country" of Darwin's comments.

The pollen assemblage is dominated by Chenopodiaceae-Amaranthaceae, Poaceae and Asteraceae. Pollen grains that reflect the shrub and thorn scrub plant communities include among others the families Rhamnaceae (*Condalia microphylla*, or *piquillín*), Papilionaceae (*Geoffroea decorticans*, or *chañar*) and Mimosaceae (*Prosopis algarrobo*). The pollen assemblage represents the modern halophytic steppe and psammophytic herbaceous steppe vege-

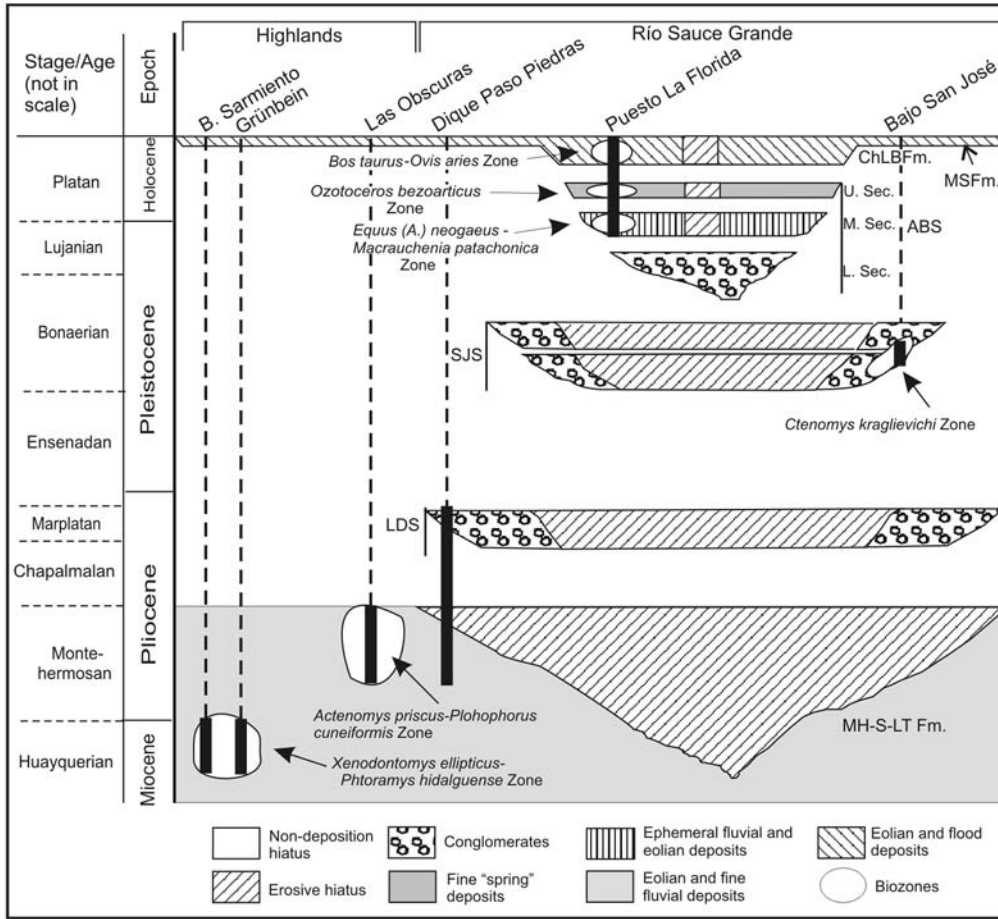


Figure 9: Chronostratigraphic chart showing space-time correlation of the geologic events in the area. ABS, Agua Blanca Sequence; ChLBFm., Chacra La Blanqueada Formation; LDS, La Delta Sequence; MH-S-LT fms., Monte Hermoso-Saldungaray-La Toma formations; MSFm., Matadero Saldungaray Formation; SJS, San José Sequence. Thick black lines indicate the levels exposed at each locality.

tation, along with shrubby woodland vegetation. Sporadic high abundances of Cruciferae probably reflect habitats subject to natural causes of disturbance such as intense eolian action under an arid climate (from Quattrocchio and Borromei 1998).

THE RECENT PAST

The Late Pleistocene/Holocene transition is characterized by development of palaeosols. During the early Holocene sea level was still lower than today; pollen records reflect the development of a vegetation community characteristic of coastal dunes. Temperature and humidity reached its maximum during the mid-Holocene when the high diversity and abundance of marine dinocysts and acritarchs indicate a transgression. This event is associated with the gramineous steppe in the continent reflecting more

temperate or local humid conditions. The relative sea level rise led to the flooding of the riverbeds, producing deposition of grey muddy facies. Approximately at 3000 years BP the marine influence ended in the area. After 2610 years BP, the development of a psammophytic herbaceous steppe suggests arid to semiarid conditions, followed by an interval of higher humidity inferred at approximately 2000 years BP, through the development of gramineous steppe communities. A relative rise of temperature may be inferred by the southward expansion of the Brazilian mammal fauna. These multidisciplinary research results are presented in a chronosequence chart synthesizing the suggested space-time correlation of the events recognized (Fig. 9). In this chart, some of the studied localities-covering the whole time interval represented in the area- were arranged in a hypothetical E-W line crossing

the Río Sauce Grande basin and the highlands. In part, this line is also approximately the one followed by Darwin when riding from Bahía Blanca to Tapalqué (*Tapalguen*) as he crossed the region toward the Río Sauce and stopped at the *second posta*.

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